SEISMIC DESIGN FOR REINFORCED CONCRETE HOSPITAL BUILDING INFLUENCED BY LEVEL OF PEAK GROUND ACCELERATION AND CLASS OF DUCTILITY

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I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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ABSTRAK

Kekerapan berlakunya gempa bumi seperti gempa di Sumatera-Andaman pada 26 Disember 2004, gempa bumi di Nias pada 28 Mac 2005, dan gempa bumi di Bengkulu pada 12 Disember 2007 telah mempengaruhi beberapa kejadian gempa di Semenanjung Malaysia. Antara tempat yang terkesan ialah di Bukit Tinggi pada 30 November 2007 hingga 25 Mei 2008, Jerantut pada 17 Mac 2009, Manjong pada 29 April 2009, dan Kuala Pilah pada 29 dan 30 November 2009. Manakala di sebelah Timur Malaysia terutamanya di Sabah, ia telah diketahuai umum sebagai kawasan yang terdedah kepada aktiviti gempa bumi. Oleh itu, ianya terbuktilah bahawa Malaysia tidak sepenuhnya bebas daripada berlakunya bencan gempa bum ini sama ada di semenanjung Malaysia mahupun di timur Malaysia. Pada tahun 2009, Jabatan Kerja Awam Malaysia (JKR) telah berpendapat untuk mempertimbangkan input rekabentuk seismik di bangunan-bangunan baru yang terletak di zon gempa yang berisiko sederhana dan tinggi. Kepentingan untuk menilai kos perlaksaan rekabentuk seismik ini amatlah dititikberatkan. Oleh itu, kajian ini telah membincangkan tentang reka bentuk dan analisa seismik terhadap bangunan hospital yang mengambil kira pelbagai nilai pergerakan tanah dan kelas kemuluran bangunan yang berlainan. Di akhir kajian ini, jumlah besi yang diperlukan untuk membina bangunan seismik ini telah dibandingkan dengan jumlah besi yang diperlukan untuk reka bentuk tanpa mempertimbangkan parameter seismik. Enam model bangunan hospital dengan pertimbangan kelas PGA dan kemuluran yang berbeza telah diambil kira, iaitu bangunan bukan seismik, kemuluran sederhana dengan PGA 0.04g, 0.08g, 0.12g, 0.16g dan kemuluran rendah dengan PGA 0.04g. Untuk magnitud yang mempunyai PGA yang berbeza, hasil menunjukkan bahawa perbezaan peratusan besi yang diperlukan berbanding dengan reka bentuk bukan seismik untuk rasuk dan lajur seluruh bangunan telah meningkat dari 6%, 116%, 257%, dan 290% untuk PGA sama dengan 0.04g, 0.08g, 0.12g dan 0.16g. Manakala bagi kelas kemuluran yang berlainan, keputusan menunjukkan bahawa perbezaan peratusan pengukuhan besi yang diperlukan berbanding dengan reka bentuk bukan seismik telah meningkat dari 6% hingga 145% untuk kelas kemuluran sederhana dan kemuluran rendah masing-masing. Natijahnya, nilai PGA dan kelas kemuluran sesebuah bangunan telah memberi kesan yang penting kepada jumlah keseluruhan besi yang diperlukan. Oleh itu, dua parameter tersebut haruslah dipertimbangkan dalam merekabentuk sesebuah bangunan seismik di Malaysia.

ABSTRACT

A series of earthquakes such as Sumatra-Andaman earthquake on 26 December 2004, Nias earthquake on 28 March 2005, and Bengkulu earthquake on 12 December 2007 had influences to a series of subsequence local earthquake in Peninsular Malaysia. Some of the local earthquake that had been affected are at Bukit Tinggi on 30 November 2007 to 25 May 2008, Jerantut on 17 March 2009, Manjong on 29 April 2009, and Kuala Pilah on 29 and 30 November 2009. While in East of Malaysia especially Sabah, it is locally known as earthquake prone region. Hence it can be concluded that Malaysia is not totally free from seismic activities either in peninsular Malaysia or at the east of Malaysia. In 2009, Malaysia Public Work of Department (PWD) felt it was worthwhile to consider seismic design input in new building which are located in medium to high risk earthquake zone. The effect of seismic design implementation on cost of materials is became an important topic to be investigated. In relation to that, this study discusses on the seismic design of reinforce concrete hospital building with consideration of different magnitude of Peak Ground Acceleration (PGA) and different class of ductility. The outcome of the design is the comparison on the amount of steel reinforcement required that is obtained from two different parameters mentioned above compared to non-seismic design. Six models of hospital buildings with consideration of different PGA and ductility class are considered, namely, non-seismic building, medium ductility with PGA of 0.04g, 0.08g, 0.12g, 0.16g and low ductility with PGA of 0.04g. For different magnitude of PGA, the results shows that the percentage difference of steel reinforcement required compared to non-seismic design for beam and column of the whole building had increased from 6%, 116%, 257%, and 290% for PGA equals to 0.04g, 0.08g, 0.12g, and 0.16g respectively. While for different class of ductility, the results shows that the percentage difference of steel reinforcement required compared to non-seismic design had increased from 6% to 145% for ductility class medium and ductility class low respectively. Thus, magnitude of PGA and class of ductility of structure give significant effect to overall amount of steel reinforcement required. Hence, it should be considered in designing a seismic building.

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LIST OF SYMBOLS

a_g	Design ground acceleration
a_{gR}	Reference peak ground acceleration
As_{prov}	Total area of steel provided
As_{req}	Total area of steel required
d_{bL}	Diameter of longitudinal bar
d_{bw}	Diameter of shear or confinement bar
F_b	Base shear force
f_{cd}	Design value of concrete compressive strength
f_{ck}	Characteristic cylinder strength of concrete
F_i	Lateral load on storey
f_y	Yield strength of reinforcement
g	Acceleration due to gravity, m/s^2
G_k	Dead load
H	Storey height
M	Bending moment
m	mass of structure
M_{Rb}	Design moment resistance of beam
M_{Rc}	Design moment resistance of column
M_w	Magnitude of earthquake intensity
n	Number of storey
q	Behaviour factor
Q_k	Live load
S	Soil factor
$Sd(T_1)$	Ordinate of the design spectrum at period
T_1	Fundamental period of vibration
T_B	Lower limit of the period of the constant spectral acceleration
T_C	Lower limit of the period of the constant spectral acceleration
T_D	Beginning of the constant displacement response range of the spectrum
V	Beginning of the constant displacement response range of the spectrum

LIST OF ABBREVIATIONS

DCH	Ductility class high
DCL	Ductility class low
DCM	Ductility class medium
$K_{elastic}$	Elastic stiffness
PGA	Peak ground acceleration

CHAPTER 1

INTRODUCTION

1.1 Background

Earthquake is considered as one of the most devastated natural disasters which had cause many human fatalities and economic losses. Earthquake happens when two blocks of the earth suddenly slip past one another, where the slip is called the fault plane. The location below the earth’s surface where the earthquake starts is called the hypocentre, and the location directly above it on the surface of the earth is called epicentre. According to (Natoli, 2005) earthquake intensity generally decreases with increasing distance away from epicentre because seismic wave amplitude gradually die down as the waves travel through the earth.

An earthquake results from the sudden release of energy stored in the lithosphere by the continuous motion of plates (Achache, 1986). Layers of the earth which are the crust and mantle made up a thin layer of tectonic plates at the surface of the earth. The boundaries of the tectonic plates are made up of many faults, since the edges of the plates are rough they get stuck while the rest of the plates keep moving. When the force of the moving plates overcomes the friction of the edges of the faults, the stored up energy will be released which will reach the earth surface and there is an earthquake.

According to Jabatan Mineral dan Geosains Malaysia (JMGM), Malaysia is considered as a country that has relatively low seismicity except for the state of Sabah where earthquake is locally known to occur (MOSTI, 2009). Because of that, Malaysia had not consider seismic load in structural design. This is due to our geographical location which are situated on the stable part of Sundaland and located far from active seismic fault region.

However, the low seismic hazard in Malaysia cannot be taken lightly as Malaysia is surrounded by high seismicity regions from neighbouring countries such as Indonesia and Philippine. According to Pappin et al. (2011), these high seismicity regions is strongly associated with the subduction zones between the Eurasian and Philippines plates at the east part as shown in Figure 1.1.

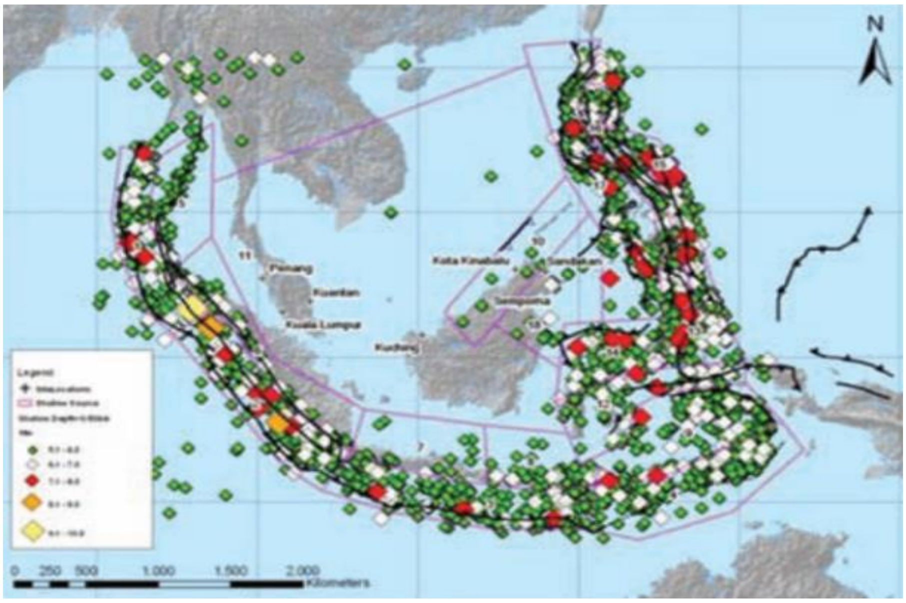

Figure 1.1 Earthquake events since 1972 to a depth of 50 km (Pappin et al., 2011)

Therefore, Malaysia will have a certain risk of earthquake coming from the regions especially in the west coast of peninsular Malaysia and Sabah. This is proven when Malaysia had been affected by a severe earthquake with magnitude M_w 9.0 that had struck Aceh, Indonesia on 26 December 2004. The ground tremor from this very strong earthquake could be felt within Peninsular Malaysia, where local earthquake had been reported in Bukit Tinggi with magnitude M_w up to 3.5 (MOSTI, 2009).

While at the east of Malaysia, particularly at state of Sabah is more prone to seismic activity. One of the worst earthquake occurred in Lahad Datu with magnitude of M_w 5.8 on 1976 which had caused damages to school building and even worse is the Ranau earthquake with magnitude of M_w 5.9 on June 2015 that had cause injuries and death to the people. This is supported by Harith (2016), where the statistics for an updated earthquake recorded from 1884 through 2016 represented by magnitude indicates a large increment of earthquake events for the last 140 years as shown in Figure 1.2.

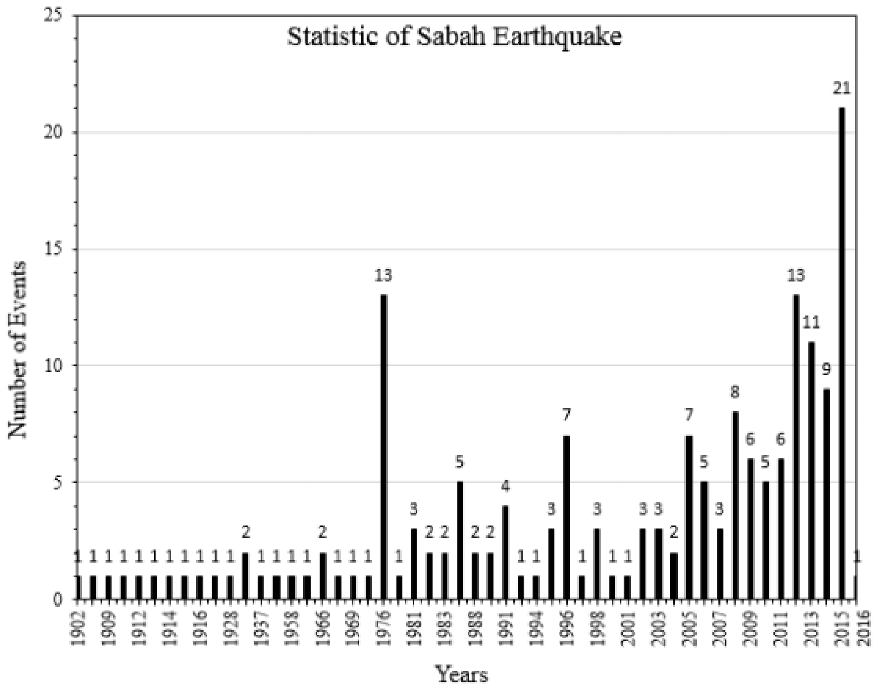

Figure 1.2 Number of local earthquakes with a magnitude greater than 2.0 reported in each decade (1900-2016) around Sabah, (Harith, 2016)

Having affected by the earthquakes, both Peninsular and Eastern part of Malaysia had been aware of the seismic hazard and necessities of applying seismic design on new buildings. Although Peninsular Malaysia has a very low seismic risk, the damage potential could not be neglected as a large earthquake from neighbouring countries could create considerably ground motion over western part of Peninsular Malaysia. Some of the degree of risk faced is when the geographical condition is composed of limestone it may cause to sinkhole development. The topographical condition with steep slopes may cause movements or landslide which may lead to damages and fatalities. On top of that, it is important to be noted that the physical size of an earthquake is not the only factor that cause damages, but it also depends on other factors such as where and when an earthquake occurred and the population density in the area concerned. The necessities on seismic research based on previous seismic activity in Malaysia is supported by Adiyanto (2016), where the M_w 5.8 Ranau earthquake in sabah has become the strongest reason on why the researches related to earthquake in Malaysia is always relevant.

There are a few factors which influencing the seismic design such as the site location, soil type, peak ground acceleration (PGA), materials, type of structures, ductility, stiffness and behaviour factor, *q* (Adiyanto, 2016). This study focused on the

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